BMW GROUP
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Looking for the next gram.

BMW EfficientDynamics means ongoing research. Exhaust heat offers the greatest potential for the future.

Munich. Even the most efficient internal combustion engine can only convert about one-third of the energy derived from fossil fuels into the mechanical kinetic energy needed to power a motor vehicle. Over the past few years BMW EfficientDynamics has made great improvements in engine efficiency, for example with technologies such as direct fuel injection, variable valve timing, exhaust-driven turbochargers, brake energy regeneration and the Auto Start Stop function. However, about 60 percent of the generated energy is still lost, half of it being exhaust heat, with the remaining half as heat absorbed by the engine cooling system. Finding ways of recovering this lost heat energy is one of the major goals being pursued by engineers working on BMW EfficientDynamics for the future. That is why the BMW Group is involved in several projects, each with different approaches to utilising dissipated heat energy, and at various levels – in research, pre-production and series development. Among the most promising innovations are the turbosteamer, thermoelectric generator, engine encapsulation and a waste heat exchanger for oil heating.

The Turbosteamer and Thermoelectric Generator (TEG) projects are focused on generating electric current from waste heat to improve overall engine efficiency, but each project follows a different approach and time frame. There is great potential for considerable fuel savings if the electrical energy required by all of the systems in an automobile can be produced using waste heat rather than relying solely on the vehicle's generator. This is another milestone behind the philosophy of BMW EfficientDynamics in achieving increased power and performance while reducing emissions and fuel consumption at the same time.

BMW turbosteamer – modelled after a power station.

In the Turbosteamer Project research and technology specialists of the BMW Group are working on a heat recovery system that is based on the principle of a steam process.

The process of recovering energy from waste heat is already practised on a large scale in modern power generation plants: large gas and steam power stations combine the principles of a gas turbine and a steam circuit to achieve a significantly higher level of efficiency. The gas turbine process is the first phase of the energy conversion and serves as the source of heat for the downstream steam cycle in the second phase.

The BMW turbosteamer is based on this two-stage stationary power generation method – but reduced in scale and design to form a component that can be used in modern automobile engines.

The first-generation turbosteamer – a maximalist approach.
Researchers proved the feasibility of this technology in December 2005 with the unveiling of the first-generation turbosteamer, which was based on a maximalist approach: they designed a dual-cycle system. The primary element was a high-temperature circuit that employed a heat exchanger to recover energy from the engine exhaust gases. This was connected with a secondary circuit that collected heat from the engine cooling system and combined this heat with the high-temperature heat from the primary circuit to create lower temperature heat.

When this design was laboratory tested on the four-cylinder petrol engines produced by BMW at the time, the dual system boosted the performance of these engines by 15 percent.

The turbosteamer today: smaller and simpler.
In order to further develop the system for use in series production, attention was given to reducing the size of the components and making the system simpler to improve its dynamics and achieve an optimized cost-benefit ratio. Thus researchers focused on designing a component having only one high-temperature circuit.

“A heat exchanger recovers heat from the engine exhaust, and this energy is used to heat a fluid which is under high pressure – this heated fluid then turns into steam, which powers an expansion turbine that generates electrical energy from the recovered heat,” explains Jürgen Ringler, Team Leader for Thermal Energy Converters at BMW Group Research and Technology. For the latest generation of the turbosteamer, engineers developed an innovative expansion turbine based on the principle of the impulse turbine, which offered many advantages in terms of cost, weight and size when compared to earlier concepts, and these are factors that are very beneficial when it comes to series production.

“We have made great progress toward achieving our original goal, which was to develop a system ready for series production within about ten years. When completed, this system will weigh only 10 kg to 15 kg and will be capable of supplying all of the electrical energy required by an automobile while cruising along the motorway or on country roads,” says Ringler. Under these conditions the developers are sure that the average driver will be able to reduce fuel consumption by up to 10 percent on long-distance journeys.

Initial integration of a mock-up system in the BMW 5 Saloon.
All of the system components developed on the test bench have been configured to form a module that can be integrated in vehicles. This has been done successfully by installing a mock-up system in the BMW 5 Saloon.

Thermoelectric generator.

Considerable progress has also been made in the Thermoelectric Generator (TEG) Project that is also focused on series production of an energy-saving component. The two alternative systems developed to date differ in their positioning in the vehicle – one unit is designed for the exhaust system, while the other is intended for the exhaust gas recirculation system. The development phase focused on integrating units in the exhaust system has led to considerable component improvements, especially in terms of weight and size.

Electricity from waste heat – a space-age solution.
The thermoelectric generator converts heat directly into electricity. The engineers of the BMW Group basically refined a technology that has been used to power space probes for more than four decades by NASA, the aeronautics and space agency of the United States. The principle behind this technology is known as the Seebeck Effect, namely that an electrical voltage can be generated between two thermoelectric semiconducters if they have different temperatures. Since the percentage degree of efficiency of TEGs was rather low, this technology was considered unsuited for automotive applications. However, in recent years progress in the area of material research has led to discoveries that have improved the performance of TEG modules.

One principle – three generations.
The first step taken by engineers was to integrate a thermoelectric generator in the exhaust system to generate electrical current. The first such system was shown to the public in 2008 and delivered a maximum of 200 watts, which was relatively low in terms of power efficiency. But the use of new materials and improvements in the weight and size of the TEGs led to rapid new developments, so that the latest generation of TEGs installed in the exhaust are capable of generating 600 watts of electrical power, and it will not be long before the goal of 1,000 watts is reached as research progresses. The current prototype – a BMW X6 – was built as part of a development project funded by the US Department of Energy.

Then in 2009, the BMW Group unveiled an alternative development in this project. Rather than installing the TEG as a separate module in the exhaust system underneath the vehicle, engineers decided to integrate the TEG in the radiator of the exhaust gas recirculation system. In this configuration, customer testing has shown that 250 watts can be generated while CO_2 emissions and fuel consumption are reduced by 2 percent at the same time.

What's more, this energy recovery system offers some interesting added benefits, such as supplying the engine or passenger compartment heating with additional warmth during cold starts. And the thermoelectric generator is the ideal counterpart for BMW EfficientDynamics Brake Energy Regeneration. While the brakes generate energy during deceleration and stopping, the TEG functions

at its best when driving is really exciting – namely during acceleration. Researchers forecast that TEGs will lead to fuel consumption savings of up to 5 percent under real everyday driving conditions in the future.

The ideal combination: heat management and BMW EfficientDynamics.

While some features of BMW EfficientDynamics, such as brake energy regeneration or the Auto Start Stop function help reduce consumption when decelerating or during idling periods, intelligent heat management can do the same when the vehicle is being accelerated and driven. In the future, even before starting the car, insulation and encapsulation of the engine compartment will ensure that the temperature of the drive train is stabilised by residual heat, thus shortening the cold start phase. An exhaust heat exchanger will also keep gearbox oil warm to reduce friction and fuel consumption as well. And a TEG or turbosteamer will supply the vehicle's electrical systems with ample power, delivering benefits when it makes the most sense – while enjoying sheer driving pleasure!

Depending on the vehicle environment and driving habits, heat management can deliver measurable benefits for specific driving scenarios. For both short and long-distance driving various features can reduce fuel consumption. Insulation of the engine compartment, gearbox oil heating with exhaust heat exchangers installed with petrol engines, or the heating function of the exhaust heat exchanger for diesel engines are features that are well-suited for vehicles that are predominately driven over short distances. During longer journeys the thermoelectric generator or turbosteamer add to that. And by utilising synergy effects, heat management will play a major role in reducing CO_2 emissions in the future.

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The BMW Group

The BMW Group is one of the most successful manufacturers of automobiles and motorcycles in the world with its BMW, MINI and Rolls-Royce brands. As a global company, the BMW Group operates 25 production and assembly facilities in 14 countries and has a global sales network in more than 140 countries.

During the financial year 2010, the BMW Group sold 1.46 million cars and more than 110,000 motorcycles worldwide. The profit before tax for 2010 was euro 4.8 billion on revenues amounting to euro 60.5 billion. At 31 December 2010, the BMW Group had a workforce of approximately 95,500 employees.

The success of the BMW Group has always been built on long-term thinking and responsible action. The company has therefore established ecological and social sustainability throughout the value chain, comprehensive product responsibility and a clear commitment to conserving resources as an integral part of its strategy. As a result of its efforts, the BMW Group has been ranked industry leader in the Dow Jones Sustainability Indexes for the last six years.